the Panama Canal," in which four locks on each slope would lead to a summit-level 130 feet above sea-level; and so by greatly reducing the excavation required in the Culebra cutting, the designer considers that the canal could be completed in four and a half years; and it is proposed that a very wide earthen dam should be formed at Bohio with materials dredged in excavating the canal, and conveyed through pipes to the site, thereby creating Lake Bohio, as shown on the plan. Another lake would be formed by a dam at Gamboa, outside the line of the canal; and this canal with locks is to be transformed into a sea-level canal, when required, entirely by dredging without impeding navigation, the dredgers being worked electrically by means of the water-power from the lake, the basin of which is to serve as a depositing ground for the dredged materials.

Admiral Chester, as an old naval officer, is naturally in favour of a sea-level canal, and supports his view by numerous extracts from the report of the Engineering Committee; whereas General Abbot, with his wide hydraulic experience, and the International Isthmian Canal Commission of 1899–1901 have advocated the construction of a canal with locks. In face of this conflict of opinion, it is natural that the United States Government referred the technical question last summer to an International Engineering Advisory Board, which recently visited the site; but, according to some newspaper correspondents, the members of this commission returned to Washington with discouraging and discordant views, so that their approaching report to the President will be awaited with much interest.

Undoubtedly, the conditions affecting the choice between a canal with locks and a sea-level canal have been modified by the United States Government having undertaken the construction of the canal, for the capital cost, which is a most important question for a private company, is of much less consequence to a Government, provided very material advantages, either as to facilities of navigation or a diminution in the expenses of maintenance, can be secured by a larger initial outlay; and, within certain limits, a prolongation of the period of construction is also of less vital importance. Too much stress, however, appears to have been laid in the report of the Engineering Committee of this year on the restriction offered by locks to navigation and increase in the size of ships, and too little account taken of the cost of enlarging a canal through an exceptionally deep cutting; and also probably much too sanguine a view is entertained of the period required for the large additional quantity of excavation necessitated by a sea-level canal, especially considering the uncertainties as to the supply of labour.

The only restrictions to navigation caused by a canal with locks are the time occupied in passing through them, and the possibility of vessels being built larger than they could accommodate; but the loss of time can be considerably reduced by suitable arrangements for filling and emptying the locks, their capacity for traffic can be readily increased by duplicating them when required, and their dimensions would naturally be made at the outset, like the tidal locks at Miraflores, adequate for any probable increase in the size of the vessels. Moreover, in the design shown on the plan, a great portion, if not the whole, of the time expended in locking would be recouped by the increased speed attained by vessels in traversing the thirteen miles of lake navigation. The advantage of facility of enlargement claimed for a sea-level canal really more rightly belongs to a canal with locks, provided the locks are constructed with due foresight of future requirements; for whereas the portions of the canal from the Atlantic to Bohio, and from the Pacific to Miraflores, with a total length of 25⅓ miles, are the same in both schemes, owing to the excavation already accomplished, as shown by shading on the longitudinal section, about 11 miles of the lake portion in the canal with locks are considerably lower than required for giving 35 feet draught of water; whilst the remaining 10½ miles of the summit-level of the canal with locks could be enlarged and deepened by 82 feet less depth of excavation throughout than would be necessary for the sea-level canal (Fig. 3).

The only serious objection that has been raised against the design shown in the illustrations is that the proposed dam near Bohio would have to be carried down 42 feet lower to reach a foundation of rock than was anticipated; but it seems almost incredible that the commissions appointed during the period that the New Panama Company had control of the works, the special mission of which it was to determine the feasibility and best means of completing the canal, should have neglected such an important investigation as the foundations for the Bohio dam. The statements that the Engineering Committee, in its report of this year, had presented the first definite plan for the construction of the canal, and that the American engineers had discovered a better site for a dam at Gamboa, which formed part of the original scheme, seem to indicate a bias against previous schemes, and a desire to appear to strike out a novel line. So far as information is at present available, and assuming that the Bohio dam can be executed as designed, it appears that a canal with locks would cost much less, be much sooner completed, and would be much more easily and cheaply enlarged than a sea-level canal, and that the greater facilities for navigation which might possibly be afforded by the larger scheme would, owing to the lake navigation offered by the other, be so insignificant as not to justify the additional cost, delays, and uncertainties the construction of a sea-level canal would entail.

Since the above article was written, the Advisory Board of Engineers has by a majority of three recommended the construction of a sea-level canal, three American and five foreigners voting in favour of it, and five Americans against, giving the preference to a canal with locks; but the report of the Board has not yet been published.

THE BIOMETRICS OF BRAIN-WEIGHTS.

"We are not endeavouring to discredit anthropology, but to furnish such branches of it as anthropometry and craniology with new tools—a little sharp-edged to the uninitiated who handle them incautiously—but which will raise anthropometry and craniology in the future into the category of the more exact sciences" (Karl Pearson, *Biometrika*, vol. iii., p. 153, 1904).

"There is a mathematical science of statistics which must be learnt, and papers dealing numerically with anthropometric and craniometric data which do not now apply this theory are simply outside the field of science" (*Biometrika*, vol. iii., p. 397, 1904).

IT is not a raid, but a victorious invasion, that Prof. Karl Pearson and his school have made into the realms of anthropology, with the result that all that part of it which deals with men in the mass becomes an annex of the mathematician. The invasion occurred at a most opportune time; great collections of data which had been accumulated by the anthropologist threatened to bury him, for he had neither the method nor the appliances for welding them into a composite whole. Especially was this the case with the endless measurements of brain-weights obtained most laboriously by the anatomist and pathologist; they urgently required an application of the "mathematical science of statistics." Hence the series of articles which occupy the greater part of a number of

Biometrika[1] published a few months ago are particularly welcome; they lay a foundation for an exact knowledge of this subject.

For a hundred years and more anatomists have sought to establish a formula by which the mental ability of any individual could be predicted from an examination of the head or brain. The problem was found to be beset with difficulties and extremely complex. How was mental ability to be standardised and measured? Is the ability shown by any individual a fair and full manifestation of his endowment, or may it be presumed that much is latent and potential? Are all the nerve structures within the cranial cavity equally concerned in the manifestation of a simple mental process, or is the organ of the mind confined to a part or parts of the brain? At an early date it was discovered that the size of the mammalian brain depended to a considerable extent on the size of the body; age and sex, too, were found to influence its weight. The weight of the brain was found to vary widely from individual to individual without any evident relationship to mental ability, so that most scientific men came to share the opinion of the unscientific, that neither the shape nor the size of the head, the volume or weight of the brain, could provide any but the most uncertain indication of mental status. Those who sought a key in the arrangement and complexity of the convolutions have not been more successful. Yet the belief that there is a close relationship between the relative size of the brain and degree of intelligence cannot be abandoned, for it is founded on a study of comparative anatomy. Amongst primates, for instance, it is found that those members which most nearly approach man in size and complexity of brain also most closely resemble him in their mental processes. It is probable, as suggested by Prof. Ray Lankester (NATURE, p. 624, April 26, 1900), that the increase in brain-weight is correlated with the substitution of voluntary or conscious for reflex, instinctive or automatic mental processes, or, in other words, the increase of brain-weight which is seen in the highest primates is the substratum of that mental quality which he has named "educability"; there is also the widespread belief that eminent men have relatively large heads. An examination of the heads of sixty distinguished men led Dr. Beddoe to the conclusion that "Intellectual distinction is generally the concomitant of largeness of brain, though there are numerous exceptions" (*Journ. of the Anthropological Institute,* p. 277, 1904). The method by which Dr. Beddoe sought to establish a correlationship between intelligence and skull capacity is regarded by Lewenz and Pearson as "quite fallacious. To begin with he selects a formula—by guesswork—which is theoretically incorrect" (*Biometrika,* p. 392, vol. iii., 1904). To sum up, anthropologists have not been able to establish, by the methods commonly in use, that there is any direct connection between the size of brain and special manifestations of human intelligence.

Turning now to the biometricians, their conclusions have the advantage of being founded on extensive collections of data, and reached by methods which are mathematically sound. In the number of *Biometrika* cited at the commencement of this article, Dr. Raymond Pearl gives the results of a biometrical analysis of 2100 adult male and 1034 adult female brain-weights, belonging to five races, Swedish, Bavarian, Hessian, Bohemian, and English. Although the matter was only a side-issue in his investigation, he sums up his conclusion as to the correlationship between brain-weight and intelligence thus:—"There is no evidence that brain-weight is sensibly correlated with intellectual ability. The limits of this correlation have been shown to be not closer than 0 and ±0·6." Here are the conclusions of other biometricians:—"There is no marked correlation between skull capacity and intellectual power" (Dr. Alice Lee). "We find the correlation sensible but so small that it is impossible to base any prediction from the size of the head as to general intelligence" (Lee, Lewenz, and Pearson, quoted from *Biometrika,* p. 392, vol. iii., 1904). There are certain circumstances, too, which must be taken into account. From about the age of twenty onwards the weight of the brain gradually decreases, a diminution which is not, as a rule, accompanied by a decrease of intelligence. Nor does the mean brain-weight of a race correspond to the mean intelligence of that race. Of the five races investigated by biometricians, the English have the smallest mean brain-weight. The mean of the adult Englishman is 27 grams less than the Bavarian mean, 57 grams less than the Hessian mean, 65 grams less than the Swedish mean, and 120 grams less than the Bohemian mean. "The order of racial average brain-weight is very far from the order of average racial intelligence. Nor is the order bettered if we allow in any manner for stature" (Blakeman). On the data at present available, one must come to the conclusion, apparently anomalous, that a big brain, so far as the manifestation of intelligence is concerned, has very little if any advantage over a small brain. The explanation of that anomaly lies with the experimental physiologist and psychologist. Meanwhile it is well to remember that under the title of brain-weight is grouped a complex of organs which are diverse in structure and in function.

If there is so little correspondence between brain-weight and brain-function the apparent preponderance of the man's over the woman's brain in weight and size loses much of its significance. It is now possible, thanks to the labours of the biometricians, to speak with a degree of accuracy and assurance as to the extent of that preponderance. The sexual difference in mean brain-weight is least among the English; the preponderance of the male in England is 100 grams (Pearson, from combined data) or 103 grams (Blakeman, from Gladstone's data); in Hesse 132 grams, in Bavaria 142 grams, in Bohemia 144 grams, in Sweden 147 grams, and in France 181 grams. In round numbers, the male preponderance is from 8 per cent. to 13 per cent. Amongst gorillas the male preponderance is 17 per cent., amongst orangs 13 per cent., amongst chimpanzees 6 per cent., and amongst gibbons 8 per cent., so that the human sexual differentiation is approximately an average amount for a higher primate. How far is the male preponderance due to greater body size? The conclusions reached by biometricians are the following:—"Differences in stature and age account for less than one-third of the observed sex-difference in brain-weight" (Raymond Pearl). "On the whole, as far as present evidence goes, we can safely conclude that there is no sensible *relative* difference in the brain-weights of man and woman, the absolute differences observed are quite compatible with the differences which result from the relative sizes of the two sexes. . . . While our results thus apparently contradict those of Pearl on p. 51 of this Journal (*Biometrika,* vol. iv., 1905) the contradiction is only on the surface, for we have been able to use a far more complete system of physical measurements" (Blakeman, Lee, and Pearson). Yet if the writer has rightly grasped the methods used, the difference between the results is due to the fact that in his calculations Pearl took into consideration merely age and stature, while the second group of workers added a third, namely, the diametrical product—a quantity which roughly represents the size of the head. To the writer, who is a professed anatomist but not an expert mathematician, it seems that one must infer from these results that nearly two-thirds of the preponderance of the male brain is correlated with the greater size of the male head, while less than one-third is correlated with the greater size of the male body, using stature as a criterion of size. Clearly, if the writer's interpretation is correct, the cause of the relatively greater weight of the male brain is still to seek, for it will be readily granted that a greater brain must be correlated with a greater size of skull. The writer is prepared to believe that the relatively greater weight of the male brain is not only correlated with, but actually dependent on, the physically greater development of the male body, for amongst the various genera of anthropoids the sexual difference in brain-weight corresponds very closely to the sexual differentiation in body size.

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[1] *Biometrika,* vol. iv., parts i, ii., June, 1905, (1) "Variation and Correlation in Brain-weight," by Dr. Raymond Pearl (with twenty-three diagrams in the text); (2) "A Study of the Relations of the Brain to the Size of the Head," by Dr. Reginald J. Gladstone (with plates ii., iii., and five figures in the text); (3) "On the Biometric Constants of English Brain-weights," by Mr. J. Blakeman, assisted by Miss Alice Lee and Prof. Karl Pearson, F.R.S. (with six figures in the text).

To what extent, then, is the weight or size of the brain influenced by the bulk of the body as measured by stature or weight? Broca *was of opinion* that each addition of 10 cm. to the stature was accompanied by an addition of 5 grams to the weight of the brain; Marshall estimated the amount at 2·4 grams.[1] "In the Swedish males, an increase of 10 cm. in stature connotes an increase in brain-weight of 28·59 grams" (Raymond Pearl); the corresponding amount in English males is estimated by Blakeman at 38·69 grams. Dr. Pearl states that the addition of 16·5 kilos. to the body-weight has the same connotation as the addition of 10 cm. to stature. In biometrical terms, the regression is linear. Such is the conclusion which must be drawn from the human data at present available; but one may legitimately infer from the limited data provided by comparative anatomists[2] that it will ultimately be found that equal additions to the bulk of the body are attended, not by equal increments to the brain-weight, but that each successive addition to the body-weight is attended by a relatively smaller increase in the brain-weight. Manouvrier found that in passing from small to medium-sized dogs the addition of each kilogram to the body-weight was attended by the addition of 2·5 grams to the brain-weight; the increment in passing from medium-sized to large dogs 1·7 grams, and from large to very large dogs 0·7 gram. Marshall concluded from Boyd's data that a somewhat similar relationship exists between the body- and brain-weight in man. Gladstone has arranged measurements made on the heads of 363 Englishmen, belonging to all classes, in four groups, according to stature, and has given the mean diametrical product for each group. The diametrical product, as Mr. Blakeman demonstrates, gives only an approximate indication of the weight of the brain; but, allowing for that, it is still remarkable that the addition to the diametrical product steadily decreases as one passes from the lower to the higher stature groups. There is also direct evidence in favour of this opinion. Levi has demonstrated that the only cells in the body which show a marked correlation in size with the bulk of the animal are the ganglion nerve cells; but the relationship is such that we must infer that every further increment to the body-weight is attended by a diminished addition to the size of the nerve cells. If the cerebral nerve mass is regarded as the governing system of the body, then one would not expect that each addition to the body-weight would be attended by the same increment to the brain-weight any more than every subsequent million added to the population of a country requires an equal addition to its administrative service.

That there is a diminution in brain-weight in old age has been accepted as a truth for many years, but until now the rate of the diminution, the periods of life at which it occurs, and its exact amount have been undetermined. Pearl found that "after the age 15–20 there is a steady though very gradual diminution in the weight of the brain with advancing age. . . . In the Swedish males, an increase of ten years in age connotes a decrease of 19·39 grams in the brain-weight." In English males, from the data provided by Gladstone, Blakeman found that the brain lost 21·97 grams each decade. Not only does the brain decrease in weight, but the head shrinks in all its diameters—at least in our English "general hospital population." The head shrinks more in height than in length or breadth; the writer has observed that the skull of the cat and the gibbon shrinks in its vertical diameter as the animal becomes aged.

The brain reaches its maximum weight at a remarkably early period. Boyd, Vierordt, Marchand, Ziehen, and Gladstone found that the heaviest brain-weights occur between the ages of fifteen and twenty, but their conclusions rest on a narrow and uncertain basis; there is a remarkable dearth of observation on the weight of the human brain between the fifteenth and twenty-fifth years. During that period the body is increasing in size; Powys found that the maximum stature occurred early in the twenty-eighth year (*Biometrika*, vol. i.); since there is a correlationship between brain- and body-weight, there ought, therefore, to be an increase in the size of the brain so long as the body continues to grow. Clearly Blakeman and his collaborators, when they exclude all subjects under the age of twenty-four, are inclined to believe that the brain reaches its prime at a later period than the material at their disposal showed. They conclude that, so far as the weight of the body organs is concerned, there is apparently not a *period*, but only an *instant* of prime. Not more surprising is the result that the brain shrinkage is gradual; one would have expected a more rapid decrease after the ages at which Huxley proposed man should be pole-axed and Osler suggested the application of chloroform.

Much of the labour of the Pearsonian school was undertaken with the view of obtaining a method by which the size or weight of brain could be calculated with a sufficient degree of accuracy in the living subject. With that end in view, they have worked out on the data provided by Gladstone the correlationship of brain-weight with eight physical characters of the body, and found that the circumference of the head and the *diametrical product* (obtained by multiplying the length, breadth, and height diameters of the head) were those which were most closely correlated with brain-weight. Their prediction formulæ (multiple regression equations) are founded on the diametrical product and circumference, with deductions or additions for stature and age. These formulæ are applied to the head of Jeremy Bentham, to a skull reputed to be Dante's, and to "one of ourselves, P." The reputed Dante is found to have a probable brain-weight which is 80 to 90 grams below the mean of the English "general hospital population" (1328 grams); Bentham, a brain which was only a few grams above the English mean; while "P's brain-weight is essentially mediocre." By the use of these formulæ the brain-weight can be predicted in the living with a probable error of 50 grams. "Nothing better can probably be achieved by introducing further external characters, or by considering regression as curved instead of plane."

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[1] See Keith, "The Growth of Brain in Man and Monkeys" (*Jour. Anat. and Physio.*, vol. xxix., p. 288. 1895).

[2] Eugen Dubois, "Ueber die Abhängigkeit des Hirngewichtes von der Körpergrösse bei den Säugethieren" (*Archiv f. Anthrop.*, Bd. xxv., 1899; *see also* Keith, *loc. cit.*).

Looking widely at the labours of the biometricians on human brain-weights, they appear to the writer, who views them as an anatomist rather than a mathematician, to have accomplished three things:—They have fixed accurately the mean brain-weights for five subraces of Europeans, and shown that mean brain-weight is a racial character; they have estimated by a definite standard the degree to which the brain varies in size and weight according to the individual, the sex, and the race; they have worked out the extent to which various features of the head and body are correlated with the weight of brain, and expressed them in definite and permanent terms. They have laid a sound foundation for future statistical work on this subject, and yet, even at the risk of appearing ungracious, it is the writer's opinion that the full explanation of the relationship which exists between intelligence, brain-weight, and other characters is more likely to be discovered by those who investigate the individual than by those who study the mass.

THE HEAD-HUNTERS OF BORNEO.[1]

WITHOUT making any pretence to being scientific, this plain and unvarnished, but eminently readable, narrative of a lady's experiences among the natives of some of the more remote districts of the interior of Borneo contains a large amount of interesting information with regard to the customs and mode of life of both Dyaks and the less well known Muruts. Mrs. Cator, it appears, accompanied her husband on his official trips into the interior of that wonderful island, and during these underwent experiences and faced difficulties such as few ladies would care to repeat, and which afford incontestable testimony as to her pluck and resolution. Among these experiences it will suffice to refer to the account of her sleeping with her husband in a large shed in company with a long row of savage head-hunters who had never before beheld a white woman, or, for that matter, a white man.

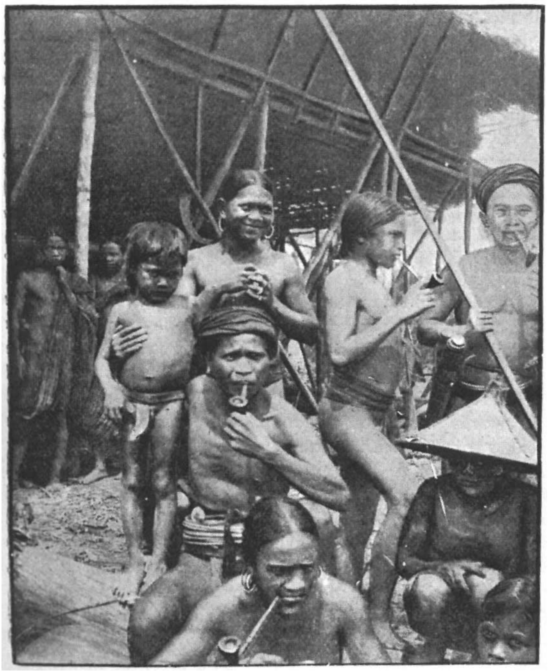

FIG. 1.—Head-hunters at Kaningau. From "Everyday Life among the Head-hunters."

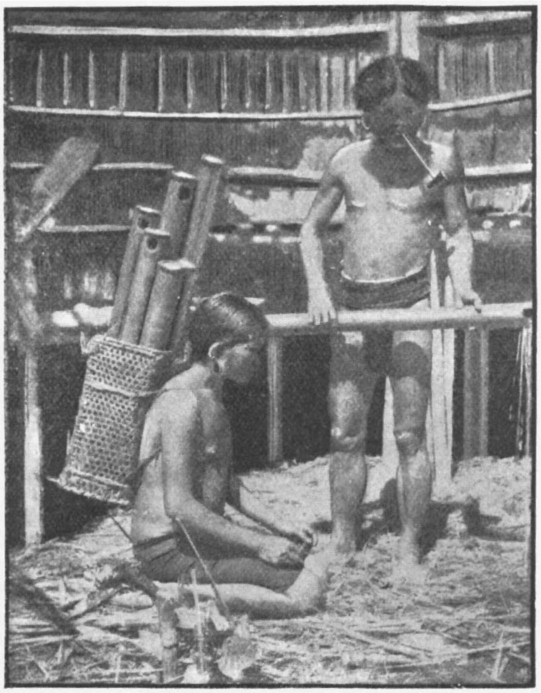

FIG. 2.—Head-hunting Chief and his wife with the bamboo water-cans they always use. From "Everyday Life among the Head-hunters."

It is, indeed, the portion dealing with the Muruts, or head-hunters, of the interior that forms by far the most interesting section of Mrs. Cator's volume, and the one which will appeal most strongly to ethnologists. The Muruts, according to the author, are a dark race compared to other races of the interior, and have certain customs peculiar to themselves, the preparation of a specially deadly form of the celebrated upas poison being one of their attributes. Although the Dyaks, except where under strict European control, are enthusiastic head-hunters, they preserve only the scalp and hair of their victims, scalp after scalp being added to their krisses with great pride. The Muruts, on the other hand, carry off and preserve the whole head as a proof of their prowess, their houses being frequently decorated with these ghastly trophies, which the author saw on more than one occasion suspended above her sleeping-place. "But there is nothing revolting in their head-hunting," writes Mrs. Cator; "they fight fairly. It is their chance of winning renown and showing what they are made of. The only low part of it is that a woman's head, owing to her longer hair, is prized even higher than that of a man; but the whole thing is a thrilling game to them, full of excitement and danger. There is nothing unfair in their warfare; both sides are doing the same, and man after man wins his spurs in feats of pluck and daring."

Despite the truculent character of their head-hunting

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[1] "Everyday Life among the Head-hunters; and other Experiences from East to West." By Dorothy Cator. Pp. xiv+212; illustrated. (London: Longmans, Green and Co., 1905.) Price 5*s*. net.